Title: BLADDER PUMP FOR BOREHOLE SAMPLING

[001] This invention relates to bladder pumps, of the kind as used when extracting a sample of e.g water from a well or other borehole in the ground.

BACKGROUND TO THE INVENTION

[002] In a conventional bladder pump, a bladder of flexible material is provided with check valves above and below. The pressure inside the bladder is controlled from the surface, the bladder being surrounded by an annular chamber having a pressure-control line to the surface.

[003] When the pressure inside the bladder is reduced to a level below the hydrostatic pressure in the borehole, water enters the bladder through the bottom check-valve. When the bladder is pressurised, the bottom check-valve closes; the increased pressure drives the water up though the upper check-valve, and to the surface, via a sample-transfer pipe.

[004] Thus, sample water from the borehole can be transferred to the surface by controlling the pressure in the annular chamber, i.e by alternately increasing and decreasing that pressure to values above and below the hydrostatic pressure in the borehole.

[005] The bladder comprises a length of thin-walled plastic tubing. This tubing is so flimsy that the tubing can readily expand and collapse. However, one of the key aspects with which the designer must be concerned is the manner by which the bladder is to be attached to the stems of its hard (metal or plastic) end-fittings. The manner of attachment must be secure against mechanical forces tending to pull the bladder off the stem, and also the attachment must be done without stressing the thin flimsy plastic material, and causing it to tear.

[006] Traditionally, bladder pumps have not been successful at small diameters. Designing a reliable manner of attaching a tube of thin flimsy plastic to a hard metal end-fitting is difficult enough when the tube is e.g twenty mm in diameter. There is a need, however, for bladder pumps having diameters in the region of six mm. The invention is aimed at providing a manner of attaching such a small-diameter tube of thin, flimsy, material to an end-fitting.

[007] One of the aspects that must be addressed by the designer of a sampling pump is the

fact that boreholes in the ground are rarely straight. Thus, the tube(s) leading down to the pump from the surface must be flexible in the sense of being able to follow the non-straightness of the borehole without becoming jammed. However, when the diameter of the pump was large, the designer could make the pump body quite short, lengthwise (i.e vertically), and thus the pump body could be of rigid material, and still follow the non-straightness.

[008] But when the diameter of the bladder is small, now the bladder needs to have substantial length (longer than e.g about sixty cm) in order for the volume of the bladder to be adequate, and now a rigid pump body would become jammed because of the non-straightness of the borehole. With a more-than-sixty-cm-long pump body, the designer will prefer to specify that the pump body be of (slightly) flexible plastic, rather than of metal. Of course, the plastic pump body is still many orders more rigid than the flimsy tubing of the bladder. The invention is especially applicable in those cases where the pump body has to be flexible.

[009] It has also been traditional, in bladder pumps, for a spine to be included inside the bladder, to keep the bladder to its shape and prevent it from collapsing completely. The new design as described herein reduces the need for such a spine; however, in some cases a spine can still be advantageous, and a spine is not ruled out in the invention.

GENERAL FEATURES OF THE INVENTION

[0010] The invention provides a way of securing a flimsy bladder-tube around and to a rigid stem. The invention makes use of a spring, i.e a helical or coil spring. The bladder-tube fits over the stem, and then the spring fits over the (thin) wall of the tube, and the spring compresses the wall of the tube onto the stem. It has been found that a bladder-tube secured in this manner can resist high pressures, and has little tendency to become torn at the point of attachment, even though subjected to frequent flexure.

[0011] The spring clamps at each end of the flexible bladder are fabricated from small diameter stainless steel coil springs. The end-fitting itself has a stem or mandrel onto which a helix (screw-thread) is formed. Preferably, the pitch of the helix is slightly larger than the pitch of the spring, as this provides preload of the spring upon assembly.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0012] By way of further explanation of the invention, exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Fig 1 shows a length of bladder-tube for a bladder pump, about to be secured to an end-fitting, in the manner of the invention.

Fig 2 is the same as Fig 1, but shows the components at a later stage of securement.

Fig 3 is the same as Fig 1, but at a still later stage.

Fig 4 is an enlarged detail of a portion of Fig 3.

Fig 5 is a cross-section of a completed bladder, assembled into the bladder pump.

Fig 6 shows a pressure control unit located at the ground surface, for use in operating the pump.

Fig 7 is a similar cross-section to Fig 5, but shows an alternative construction.

Fig 8 is a cross-section that shows a modified component of a bladder pump.

Fig 9 is a cross-section that shows another bladder pump.

Fig 10 is a cross-section that shows another bladder pump.

Fig 11 is a cross-section that shows another bladder pump.

[0013] The apparatuses shown in the accompanying drawings and described below are examples which embody the invention. It should be noted that the scope of the invention is defined by the accompanying claims, and not necessarily by specific features of exemplary embodiments.

[0014] To assemble the bladder retention system, bladder-tube 20 is first collapsed in such a manner as to allow helical coil spring 23 to pass over and along the tube, to a position approximately two cm from the end of the tube. This condition is shown in Fig 1. The bladder-tube 20 has substantially no inherent rigidity, being of thin-walled (typically, in the region of 0.1 mm wall thickness) heat-shrinkable polytetrafluoroethylene (ptfe).

[0015] The stem 24 of the (stainless steel) upper end-fitting 25 is formed with a shallow single-start-helical groove 26. The groove is e.g 0.02 mm deep. The groove profile is gently rounded, and is so shaped, in relation to the spring, and to the thickness of the bladder material, such that the wall of the bladder-tube, upon being squeezed into intimate touching contact with the stem, leaves no gaps (potential leakage paths) in the profile.

[0016] The open end of the bladder-tube 20 is placed over the stem 24. The end portion 27 of the bladder-tube is heated, whereupon the ptfe material shrinks, such that, over a heat-

shrunk area 28, the bladder-tube now conforms to, and grips lightly around, the stem 24, being the condition as shown in Fig 2. As shown, the heat-shrunk area 28 of the bladder-tube extends a little way past the stem. An extension or nose 24a on the end of the stem 24 keeps the heated area from becoming distorted.

[0017] The spring 23 is drawn forwards, over the heat-shrunk area 28, and threaded over the stem 24. The dimensions of the components are such that the spring 23 has to be expanded slightly in order for the spring to be screwed onto the groove 26, over the thickness of the ptfe material. The result is as shown in Fig 3, and in detail in Fig 4. This operation can be carried out by a person, by the use of the fingers (although the assembly may be automated).

[0018] Heat-shrunk thin-walled ptfe tubing can be held very securely to the stem of the end-fitting by this technique. The manner of securement imposes very little stress-concentration in the flimsy bladder material, although care should be taken to ensure that portions of the stem with which the tubing comes in contact are smooth and rounded. The manner of securement has been found to be mechanically strong, and more than adequate both against forces tending to pull the bladder-tube axially off the stem, and against pressure forces, internally and externally of the bladder.

[0019] In use for extracting samples from boreholes, the bladder may be subjected to a pressure differential in which the pressure outside the bladder exceeds the pressure inside by around 10 psi, and a reverse differential also of around 10 psi.

[0020] The other end of the bladder-tube 20 is secured to the stem 29 of the bottom end-fitting 30 by the same technique.

[0021] As shown in Fig 5, the assembled bladder 32 is placed inside a pump-outer-tube 34. The pump-outer-tube 34 is of thick-walled polyethylene or ptfe, having a wall thickness of around 1.5 mm. The tube 34 is inherently self-supporting, being much thicker and stiffer than the (flimsy) bladder-tube 20. Such plastic tubing is flexible, however, in the sense that the tubing can be bent to a (gentle) arc, which is what is needed if the bladder pump is to be fed through tight narrow clearances -- given that drilled boreholes in the ground and the pipes and tubes used therein are usually not quite straight. The plastic pump-outer-tube 34, however, is rigid when it comes to resistance to pressure, i.e in the sense of resistance to hoop or circumferential stresses. Pressure differentials to be supported by the pump-outer-tube would typically be around 100 psi, which the described kind of tubing can easily support.

[0022] Alternatively, the pump-outer-tube can be made of metal or more rigid plastic.

[0023] The bottom end-fitting 30 of the bladder 32 includes the barbed stem 29, to which the lower end of the pump-outer-tube 34 is secured. The bottom end-fitting 30 includes a check valve in the form of a (stainless steel, or ptfe) ball 36, which settles against a seat 37 if pressurised from above, and allows fluid to pass through the fitting 30 if pressurised from below. A filter (not shown) may be incorporated into the bottom end-fitting 30, for filtering the water sample taken in from the borehole.

[0024] The upper end-fitting 25 of the bladder includes a long-tube 38, which fits inside the central bore 39 of an outer adapter piece 40. The long-tube 38 is a loose fit inside the adapter-piece 40, and is not attached to the adapter-piece. A shoulder 42 on the upper end-fitting 25 limits the extent to which the long-tube 38 can travel upwards into the adapter 40. The shoulder 42 is angled to ensure that, even if the shoulder were in contact with the lower end-face 41 of the adapter 40, fluid can pass freely, past the shoulder 42, around the long-tube 38, and through the bore 39.

[0025] The upper end of the long-tube 38 is barbed to receive a sample-transfer-tube 43, which is a length of thick-walled ptfe or polyethylene tubing that extends to the surface.

[0026] The bottom end of the sample-transfer-tube 43 is fitted with a check-valve. A collar 46 is first inserted into the sample-transfer-tube 43. This collar grips the tube 43 internally. A stainless steel ball 47 provides the check-valve function, in combination with a suitable valve-seating provided in the top end-face of the long-tube 38. The collar is angled as to its bottom end-face, which is so arranged that the ball cannot seal thereagainst. When the sample-transfer-tube 43 is barbed to the upper end of the long-tube 38, the valve member 47 is trapped inside.

[0027] Alternatively, the ball in the check-valve may be replaced by a valve member of another shape. One favoured form of valve member is as a plastic extrusion of a three-lobed profile, machined at its bottom end to an appropriate cone to suit the valve seat. The check-valve function requires that the valve should seal tightly when pressurised from above; therefore the valve-member 47, the valve seat, and the ports in the valve housing, should be so arranged that, when the valve is pressurised from below, the valve member cannot inadvertently close off the passageways, but rather so that water can pass freely up through the open valve.

[0028] In Fig 5, the long-tube 38 can float, vertically, inside the adapter 40. The long-tube is limited as to its upwards movement by the engagement of the angled shoulder 42 with the bottom end-face 41 of the adapter, and is limited as to its downwards movement by the engagement of the bottom end of the barbed-on sample-transfer tube 43 with the upper end-face 44 of the adapter.

[0029] At the surface, as shown in Fig 6, a manifold 50 is provided. The sample-transfer-tube 43 passes right through the manifold, for conveying the sample to a suitable receptacle at the surface. The main-outer-tube 49 communicates with the drive port 53, through which the annular space 54 between the main-outer-tube 49 and the sample-transfer-tube 43 can be pressurised (with air, or other gas). The annular space 54 communicates with the space 56 (Fig 5) between the bladder-tube 20 and the pump-outer-tube 34. By pressurising this space 56 (i.e by pressurising the space 54), the bladder 32 can be made to collapse.

[0030] In use, the drive port 53 is alternately pressurised and de-pressurised. When the space 56 is de-pressurised, the bottom check valve opens and water from the borehole enters the bladder 32. The upper check valve opens also if the pressure in the sample-transfer-tube 43 is below the borehole pressure of the sample of water entering the bladder.

[0031] Next, the space 56 is pressurised (from the surface), which causes the bladder to collapse. The bottom check valve closes, and the upper check valve opens, so the sample is pumped out of the bladder, upwards into the sample-transfer-tube 43. By continually raising and lowering the pressure supplied to the port 53, water can be pumped out of the borehole, and into the surface receptacle.

[0032] It will be noted that the bladder 32 is mechanically attached to the pump-outer-tube 34 at the very bottom of the pump, and the sample-transfer-tube 43 is attached to the manifold 50 at the sampling port 52. Apart from those attachment points, the sub-assembly of the bladder 32 and the sample-transfer-tube 43 is free to float in the space inside the outer tubes 34,49 and inside the adapter 40. This free floating aspect is important in avoiding unpredictable stresses in the flimsy material of the bladder-tube 20, and in permitting the pump, as an assembled structure, to be flexible enough to pass freely up and down the narrow and not-quite-straight passageways.

[0033] It has been found that, when the coil spring 23 is screwed onto the stem, trapping the ptfe tubing 20 therebetween, the tubing does not tend to become twisted. That is to say, the tubing remains fixed to the stem 24, and the spring rotates around the tubing. In fact, the

tubing is so flimsy that, if the tendency were for the tubing to be dragged around with the spring, not much could be done, e.g by way of gripping the tubing, to resist that tendency.

[0034] Assembly of the bladder itself is simple enough, at least as a manual operation, in that the bladder (i.e the bladder-tube and its two end-fittings) is completed as a unit before the bladder is assembled into the outer tube. Of course, some care is needed when carrying out assembly work on the bladder, as it is all too easy to damage the thin-walled tubing.

[0035] Fig 7 shows an alternative design. Here, the adapter-piece 40 has been omitted, and the pump-outer-tube 34 and the main-outer-tube 49 are one and the same. Now, the bladder upper end-fitting 60 is completely floating inside the outer tube 62. This arrangement is simpler than that of Fig 5, and can be suitable for shallow boreholes. In Fig 7, the components of the bladder pump are mechanically supported entirely by being suspended from the foot of the sample-transfer-tube 43, and not at all from the main-outer-tube 49; this manner of support is not suitable for the deeper systems.

[0036] The problem of attaching a flimsy tube to a stem, in a manner that leaves the attachment mechanically strong, and pressure-resistant, is exacerbated when the overall diameter of the tube is very small. In the case as depicted in the drawings, the ptfe heat-shrinkable tubing from which the bladder is made is six mm in diameter. The stem onto which the heat-shrunk end of the bladder-tube is secured is nominally 4.5 mm in diameter. The coil spring is made of round wire, of ¾ mm diameter, and is about seven coils in length. It is wound to a helix of such diameter that, if the bladder-tube 20 were not present, the spring would just about slide axially over and along the stem.

[0037] It may be regarded that the invention comes into its own when the bladder-tube material is so flimsy that the material has substantially no inherent rigidity, and when the tube diameter is below about fifteen mm, and especially below about ten mm. Above that size, or when the tube material is more rigid, other ways of attaching the tube to the stem of a fitting can be more economical.

[0038] Attaching an under-ten-mm-diameter thin ptfe tube to a stem, in a manner which leaves the attachment able to resist quite high pressures, and to resist continual flexing of the tube wall, is a difficult problem. Properly serviceable bladder pumps are readily available in sizes above about ten or fifteen mm bladder diameter, but traditionally, below that diameter, the pumps that have been available have been notoriously fragile, and prone to leakage and other problems. The manner of attaching the bladder as described herein may be expected to

alleviate the robustness problems.

[0039] The reduced diameter of the pump of course means that, in order to achieve good sample volumes, the bladder must be quite long. Thus, where a fifteen mm bladder pump may be say sixty cm long, the six mm bladder pump should be 1.5 metres long. The long length of the bladder means that the difference between the inside/outside pressure differential at the top of the bladder can be a significantly larger than the differential at the bottom of the bladder. Thus, the bladder in a long, small-diameter pump is called upon to support greater differentials than the bladder in a shorter, larger-diameter pump. Even so, the manner of attachment as described herein is more than adequately equal to the task.

[0040] The designer may specify that the space 56, and the space 54, be partially filled with water or other liquid. This can assist in reducing pressure differentials between the insides of the tubes 43,20 and the spaces 54,56 without affecting pump operability.

[0041] In the larger diameters of bladder, the task of screwing a coil spring over tubing, over a stem, becomes a little more difficult, and, as mentioned, traditional ways of attaching thin-walled tubes to stems are acceptable when the diameter is large. However, the technique of the screwed-on coil spring over heat-shrunk tubing, as described, may be used in the larger diameters.

[0042] Because of the small volume of a small-diameter bladder, it can sometimes be a problem to extract samples at a high flowrate, where that is a requirement. In that case, several bladders may be provided. The several bladders are separately operated (by being pressurised from above), but all the bladders discharge into a common sample-transfer-tube leading to the surface. Several independent small-diameter bladder pumps can be more flexible, and easier to lower down to deep depths, than one large-diameter pump.

[0043] Fig 8 shows a modification to the manner in which the long-tube 38 of Fig 5 interacts with the adapter 40. A problem that can happen in Fig 5 arises from the fact that long lengths of plastic tube is usually transported and stored in coils. Stored thus, the tubing takes on a set to the curvature.

[0044] Thus, the main-outer-tube 49 (and the pump-outer-tube 34) can have acquired a slight curvature. The outer tube might be dozens (sometimes hundreds) of metres long, whereby the bottom end of the tube can easily lie slightly twisted relative to the top end of the tube. What can happen is that, as the apparatus is being lowered into a borehole, and the borehole

perhaps imposes its own slight curvature onto the slightly curved tubes, the bottom end-fitting 30 might suddenly flip through 180 degrees.

[0045] It can happen that the sample-transfer pipe 43, being not mechanically connected to the outer-tube 49, does not follow this rotation. In that case, effectively, the bottom end of the bladder-tube 20 has been twisted relative to its top end. (The bladder-tube 20 itself has no resistance to being twisted.) The bladder-tube 20 is of the order of only a metre or two long, whereby a 180 degree twist in the bladder-tube can be quite disruptive to the operational integrity of the bladder. (It will be noted, also, that the operators would not know that such disruption had taken place.)

[0046] The problem can be solved by locking the upper end-fitting at the upper end of the bladder to the adapter, and thus to the pump-outer-tube 34. The pump-outer-tube 34, being only a metre or so long, has a very strong resistance to being twisted. Thus, where the upper-end-fitting is locked, torsionally, to the adapter-piece, effectively the bladder is thereby protected from this disruptive twisting.

[0047] As shown in Fig 8, locking the upper-end-fitting of the bladder to the adapter piece 40 can be done by forming a kink in the long-tube 72, whereby the long-tube now has a friction grip in and to the hollow bore 73 of the adapter 40.

[0048] In Fig 8, the main-outer-tube 49 might still undergo a sudden flip through 180 degrees, but now the upper end of the bladder is constrained to follow that motion. That is to say, the sample-transfer-tube 43 now suffers the twist through 180 degrees; but, being long, the sample-transfer-tube is easily able to accommodate this.

[0049] The kink in the long-tube 72 is so shaped as to leave ample room for air (or another fluid) to pass through from the annular space 54 to the annular space 56, whereby the kink does not interfere with the ability to pressurise the annular space 56 from the surface.

[0050] As mentioned, in Fig 7, there is no adapter piece 40, and the pump components take all their mechanical support from the sample-transfer-tube 43. In Fig 5, by contrast, the pump components are mechanically supported from the adapter piece 40, in that although the pump components can float vertically relative to the adapter, they can do so only through a limited travel. As mentioned, the pump components are prevented from moving too far downwards by the engagement of the bottom face 51 of the sample-transfer-tube against the top face 44 of the adapter; similarly the pump components are prevented from moving too far upwards by

the engagement of the shoulder 42 of the long-tube 38 with the bottom end-face 41 of the adapter-piece 40.

[0051] In Fig 5, the length of the pump-outer-tube 34 should be arranged such that, upon assembly, the long-tube 38 is more or less in the centre of its permitted travel relative to the adapter-piece. The bladder-tube 20 should not be stretched more than about ½cm per metre. Equally, the bladder-tube should be straight, i.e should not be concertinaed, and again the bladder-tube should not be more than about ½cm per metre longer than the length into which it fits.

[0052] The designer will prefer, in many cases, to arrange for the bladder components not to float at all relative to the adapter, but for the bladder to be mechanically fixed into the adapter -- as in Fig 8. Where the bladder cannot float at all relative to the adapter, care must be taken to cut the length of the pump-outer-tube 34 to correspond more or less exactly to the length of the bladder-tube 20, so that the bladder-tube is neither stretched nor concertinaed, within about ½cm per metre, and preferably within ¼cm per metre.

[0053] Fig 9 shows another way of attaching the long-tube 76 into the adapter 40. Here, the long-tube 76 is unitary with the upper-end-fitting 25. (The long-tube may be tack-welded or silver-soldered into the upper end-fitting, as shown in Fig 5, or the two components may be machined together from one single piece of metal.) In Fig 9 the angled shoulder 42 of the upper-end-fitting 25 is soldered or welded to the bottom end face 41 of the adapter 40. In arranging the manner of attachment to the adapter piece, the designer must see to it that there is a fluid communication between the space 54 above the adapter and the space 56 below the adapter, for inflating/deflating the bladder, and that this combined space is sealed from the water sample travelling up from the bladder 20 into the sample-transfer-tube 43.

[0054] In Fig 9, the sample-transfer-tube 43 is attached to the top end of the long-tube 76, and is held securely in place by means of a crimped-on band 78. (Preferably, in the drawings generally, corresponding crimped bands are used (though not shown) wherever the various tubes are attached to the barbed ends of the various fittings.)

[0055] In the alternative construction shown in Fig 10, the check valve is built into a housing located in the upper end-fitting. Here, the check valve 80 is located actually within the upper end-fitting, rather than in the sample-transfer-43 tube above the upper end-fitting. In Fig 10, the upper end-fitting is in two parts 82,83 which are screwed together. In fact, the upper portion 82 of the fitting is unitary (i.e machined in one-piece) with the long-tube 84. The ball

85 of the check valve 80 prevents the sample of water from moving back down into the bladder 20; the ball 85 is prevented from rising too far by a pin 86, which straddles across, and is sealed into, the sides of the fitting 83.

[0056] In Fig 10, the sample-transfer-tube 43 is barbed onto the top end of the long-tube 84. The main-outer-tube 49 (not shown in Fig 10) is barbed onto the upper end of the adapter piece 40, and extends up to the surface.

[0057] In Fig 10, as in Fig 5, the long-tube can float vertically relative to the adapter piece 40. Thus, the upper extremity of the fitting 82, and the lower extremity of the sample-transfer-tube 43, are angled, to ensure that they cannot close off air flow through the faces against which they might abut.

[0058] In Fig 11, the upper end-fitting is combined into the structure of the adapter piece 90. The long-tube 92 is soldered into the adapter piece 90. The lower extremity of the soldered-in long-tube 92 is angled, in order that the check-valve ball 93 does not close off thereagainst. Communication between the upper annular space 54 and the pump annular space 56 is via holes 94.

[0059] In the drawings, the annular space 56 between the bladder-tube 20 and the pump-outer-tube 34 is shown as a large diametral gap. This is just for clarity of illustration: in fact, the nominal diameter of the bladder should be such that the bladder does not have to expand in order to touch the inside face of the pump-outer-tube 34. That is to say, the bladder-tube 20 should be the same size as the inside of the pump-outer-tube. The designer should see to it that, when the pressure inside the bladder (i.e the borehole pressure) is greater than the pressure outside (as applied from the surface), the bladder-tube is substantially not stretched.

[0060] Thus, although the component is referred to as a bladder, which might imply stretching, and of course some degree of stretching is inevitable in a sealed and pressurised bladder, still the designer should take steps to prevent or minimise all stretching of the material of the bladder. The pump should be designed so that when the bladder is pressurised internally, the walls of the pump-outer-tube keep the bladder from expanding beyond its nominal or unstretched dimensions; and so that when the pressure applied at the surface is greater than the borehole pressure the bladder collapses by becoming flattened.

[0061] It is to be noted that when ptfe is heated, and shrunk, it undergoes a structural change, and becomes more rigid. Thus, the heat-shrunk areas 28 of the bladder tube 20 are

a little more resistant to being expanded and stretched than the rest of the bladder tube when the bladder is subjected to internal pressure, which is beneficial because it is in the area around the points of attachment that it is more difficult to ensure containment of the expansion.